International Journal of Nanotechnology and Application (IJNA)
ISSN(P): 2277-4777; ISSN(E): 2278-9391
Vol. 4, Issue 4, Aug 2014, 9-12

TRANS STELLAR • Journal Publications • Research Consultancy

MAGNETIC FIELD INDUCED STRAIN IN BORON DOPED NIMNGA FERROMAGNETIC SHAPEMEMORY ALLOY

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ABSTRACT

The magnetic field induced strain (MFIS) is key parameter for determining the ferromagnetic shapememory alloys (FSMAs) for the application of sensors and actuators. NiMnGa based FSMAs, having higher magnetic field induced strain was found to be prototypes for these applications. But, because of their brittleness using them practically is very difficult. To increase its ductility we have doped boron to the NiMnGa. We have made $Ni_{50}Mn_{30}Ga_{19.5}B_{0.5}$ alloy samples using the arc melting method and annealed and characterized using X-ray diffraction (XRD), Scanning Electron Microscope (SEM) and EDAX. The transformation temperatures were obtained from the four probe resistivity and DSC measurements (from 80 K to 400 K). Magnetization was measured with VSM (80 K-400 K) to know the Curie temperature (T_c). The transformation temperatures were found to be T_{Ms} = 340 K, T_{Mf} = 314 K, T_{As} = 325 K and T_{Af} = 357K and T_c = 373 K.. The MFIS at room temperature was determined using a strain gauge attached to the sample which was kept in a d.c. electromagnet of maximum field 1.5T and data was obtained from a TML TDS data logger. The results of such measurements are presented in this paper.

KEYWORDS: Ferromagnetic Shape Memory Alloy, Resistivity, Strain Gauge and Magnetic Field Induced Strain

INTRODUCTION

Ferromagnetic Shapememory Alloys (FSMAs) are being intensively studied because of their smart nature and potential candidates for the applications in sensors and actuators. In FSMAs the martensitic transformation and lattice reorientation processes can be controlled or triggered not only by stress or temperatures but also with the magnetic field [1, 2]. The prototypes for this application are NiMnGa based FSMAs, because of their brittleness using them practically is very difficult [3]. Here we have doped boron, to increase its ductility so that enhances its applicability. It was also found from the literature that the boron addition to NMG stabilizes the martensite [4] and also increase the ductility. The main purpose of this work is to prepare and characterize the boron doped NiMnGa FSMA alloy and obtain its structural and magnetic transformation temperatures and measure its MFIS using a strain gauge. There are several methods[5, 6] that the researchers were adopted, for measuring the strain of these Ferromagnetic Shape memory alloys but we have chosen the strain gauge method [7], because it is cheap and best method. The MFIS which is a useful and important parameter that gives the information of magnetic field induced strain of the sample which in turn decides the application of the present samples for the sensors and actuators application.

RESULTS AND DISCUSSIONS

The NiMnGa alloy with the composition $Ni_{50}Mn_{30}Ga_{19.5}B_{0.5}$ was melted several times in the arc furnace and annealed at 900C for 6 hours. The sample was then characterized by using the XRD, SEM and EDAX. The DSC measurements were done with-in the temperature range of 80 K to 400 K. The room temperature MFIS measurements were done using a Polytronic d.c. electromagnet which can produce a maximum field of 1.5T in both the directions and TML TDS data logger and a TML cryogenic strain gauge attached to the sample. The arrangement was first calibrated using a Terfenol-D sample, which has a highest value of magnetostriction. The strain gauges were attached to the samples with the appropriate epoxy and kept in the tapered poles of the magnet. From the DSC the transformation temperatures were determined and they are T_{Ms} = 340 K, T_{Mf} = 314 K, T_{As} = 325 K and T_{Af} = 357K and are shown and marked in the Figure 1. Figure 2 shows the Magnetization Vs Temperature plot for the present sample from this plot the Curie temperature was obtained and the T_c = 373 K.

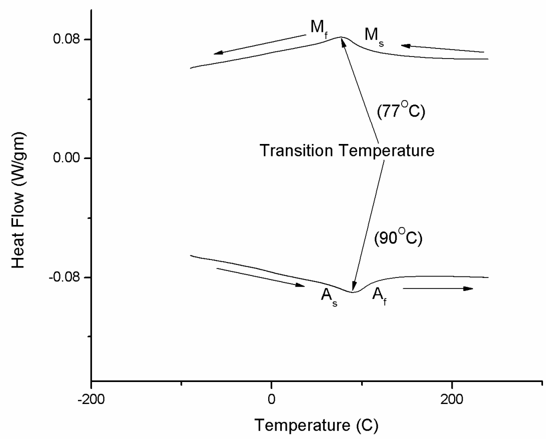

Figure 1

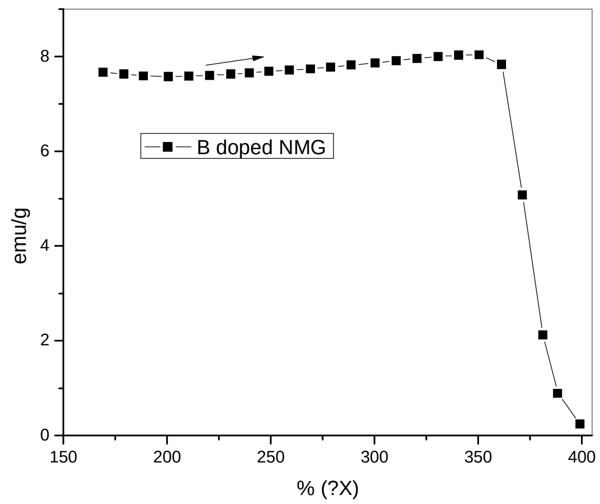

Figure 2

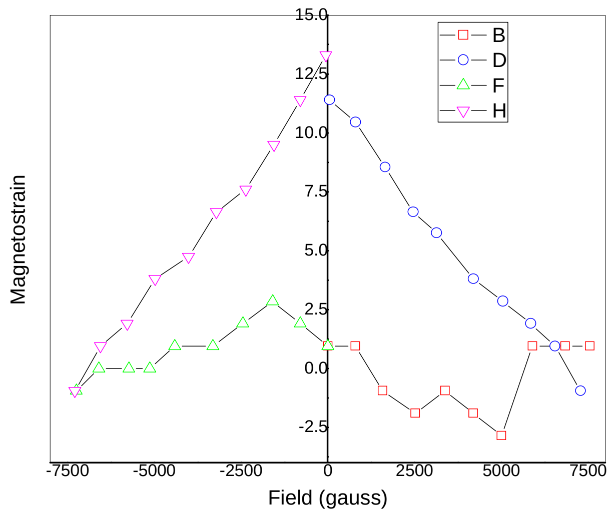

Figure 3(a)

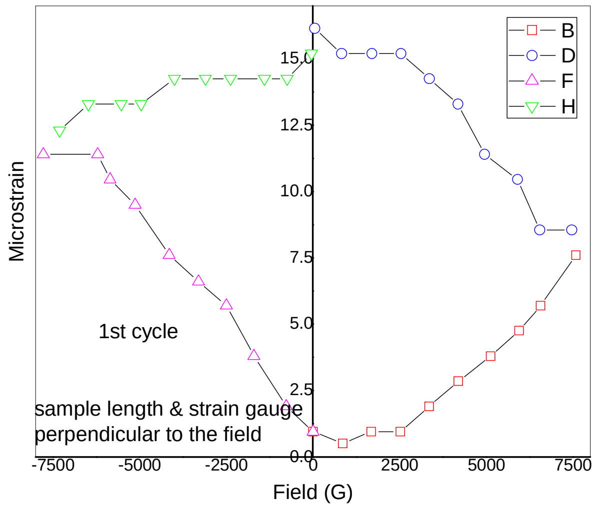

Figure 3 (b)

Figure 3 (a, b). shows the magnetic field induced strain measured with field parallel and perpendicular to the sample strain gauge arrangement.

From the figure 3(a) the sample arrangement is parallel to the field, it can be observed that the strain initially slightly negative and pickedup with the field and while coming back raised to 12.5 microstrain. In the other direction of the magnetizing current the strain decreased and gone to –ve side and picedup when the field is maximum in the reverse direction and made almost same microstrain to reach the earlier curve, where as the Figure 3(b) shows a opposite behavior when the field is increased in the positive side the strain increased and gone to 7.5 microstrain and from there it still raised when the field is reduced to meet at 15.5 microstrain and in the reverse side also it have behaved similarly but reached here

to 12 microstrain and when the field is reduced strain increased slowly to reach at 15microstrain. The asymmetry is attributed to the sensor and study of directionally solidified, single crystalline samples is underway for the better understanding of the behavior.

CONCLUSIONS

- From DSC measurements the structual transformation temperatures of the sample were found and they are T_{Ms} = 340 K, T_{Mf} = 314 K, T_{As} = 325 K and T_{Af} = 357K
- From the Magnetization measurements the Curie temperature of the sample was found to be T_c = 373 K
- From the Magnetic Field Induced Strain measurements the present sample has a maximum strain of 12.5 microstrain which is quite less than the undoped NMG samples. This is the first and most important observation in the present study

ACKNOWLEDGEMENTS

The authors acknowledges the support extended by DST and also for granting DST FAST TRACK Project No. DST/FTP/PS-108/2009 to the author BRK. The author BRK is also thankful to the Directors, S.N. Bose Center, and T.K.R College of Engineering and Technology for the collaboration work. The Secretary and Treasurer were also thanked for thier constant help and support to do the R&D work in the College.

REFERENCES

1. M. A. Marioni, R. C. O'Handley and S. M. Allen, *Appl. Phys. Lett.* 83 (2003) 3966.
2. C. P. Henry, D. Bono, J. Feuchtwanger, S.M. Allen and R.C. O'Handley, *J. Appl. Phys.* 91(2002) 7810.
3. V.A. Chernenko, E. Cesari, J. Pons and C. Segui, *J. Mater. Res.* 15 (2000) 1496.
4. Bhoj Raj Gautam, Igor Dubenko, Arjun Kumar Pathak, Shane Stadler, Naushad Ali, *Jour. Mag. Magnetic. Materials* Vol. 321 29 (2009)
5. M. Rotter, H.Muller, E, Gratz, M. Doerr and M. Loewenhaupt. *Rev. Scientific. Instru.* 69 7 (1998)
6. H. Morito, A. Fujita, k. Fukamichi, R. Kainuma and K. Ishida, *Appl. Phys. Lett* 81 9 (2002)
7. J. Liu, H. Zheng, Y. Huang, M. Xia, J. Li, *Scripta Materiallia* 53 29(2005)